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ABSTRACT

This multi-participant case study used a phenomenological lens to understand the ways that science teachers make sense of implementing instructional innovations following their participation in a year-long biotechnology professional development program. Sources of data included a series in-depth interviews used to collect teachers' stories of implementation of biotechnology lessons and field notes taken by the researcher while conducting site visits. Data were analyzed inductively with pattern coding strategies allowing for the emergence of within and across participant themes associated with volitional implementation. Three assertions were generated: (1) implementers consistently reported a dynamic view of curriculum that enabled their incorporation of innovations; (2) within this dynamic view, they held tacit, implicit, personal goals and purposes for teaching science and reported pedagogical practices that were congruent with their goals despite common constraints; and (3) these teachers possessed a deep sense of professionalism that drove them to implement innovations in their quest to meet their goals. The findings of this study were used to generate recommendations for research, policy, and practice associated with the professional development of teachers and the design and implementation of reform oriented curricula. (Contains 26 references.) (Author/MM)

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Stories of teaching biotechnology:

A case study of volitional curriculum implementation

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This multi-participant case study used a phenomenological lens to understand the ways that science teachers make sense of implementing instructional innovations following their participation in a yearlong biotechnology professional development program. Sources of data included a series of in-depth interviews used to collect teachers' stories of implementation of biotechnology lessons and field notes taken by the researcher while conducting site visits. Data were analyzed inductively with pattern coding strategies allowing for the emergence of within and across participant themes associated with volitional implementation. Three assertions were generated. a) Implementers consistently reported a dynamic view of curriculum that enabled their incorporation of innovations. b) Within this dynamic view, they held tacit, implicit, personal goals and purposes for teaching science and reported pedagogical practices that were congruent with their goals despite common constraints. c) These teachers possessed a deep sense of professionalism that drove them to implement innovations in their quest to meet their goals. The findings of this study were used to generate recommendations for research, policy and practice associated with the professional development of teachers and the design and implementation of reform oriented curricula.

Introduction and Review of the Literature

Reform efforts on a national policy level during the 1980s and 1990s have resulted in the development of national goals for science education. These national goals emphasize science content presented as inquiry into unifying and integrated concepts within a context students find relevant, and in a classroom environment where students work together as active learners (National Research Council [NRC], 1996; American Association for the Advancement of Science [AAAS], 1993). However, research in the area of professional development suggests that the implementation of reform-based ideas has been erratic and unpredictable (Bybee, 1997). An unfortunate incongruity between goals and theories generated by educational researchers and the prevalent practices of our dominant educational system (Cochran-Smith & Lytle, 1990; Hurd, 1991) remains prevalent.

Sometimes, teachers are not even aware of new reform initiatives and national policy documents (Dinucci, 1997). The products of research in science education are not easily accessible to teachers and, as a result, are mostly ignored by them (Hurd, 1991). With the exception of the currently popular action research projects (e.g. Hodson & Bencze, 1998), teachers often have neither a stake in the results of the research efforts, nor a reason to pay attention. Research results have been seen as outside the realm of the reality that teachers face daily, and taken as just another piece of irrelevant advice that would soon be replaced by a different wave of reform (Martin, 1999). In order to decrease the incongruity and facilitate reforms in school science, curriculum designers, science teacher educators, providers of professional development for science teachers and

administrators must acknowledge the crucial role of teachers in the successful implementation of these standards and benchmarks.

Existing studies of implementation use both quantitative and qualitative methods. Curriculum implementation research from the 1970s and 1980s were largely reports of levels of implementation and factors affecting implementation using quantitative measures such as questionnaires and surveys (Hall, et al, 1975; Aylen, 1978; Crocker & Banfield, 1986; Guskey, 1988). More recently, qualitative researchers have addressed issues of teacher change. Research on teacher change indicates that barriers exist within the individual perceptions of some teachers, impeding changes in the teaching of science, and reflecting their responses to contextual requirements (Czerniak & Lumpe, 1996; Sanchez & Valcarcel, 1999; Yerrick, Parke, & Nugent, 1997). These barriers are described as conflicting beliefs about teaching, learning, and the nature of science and science curricula (Crocker & Banfield, 1986; Cronin-Jones, 1991; Silva, 2000). Many of these barriers appear in the form of cultural myths (Tobin, Tippins, & Hook, 1992). The beliefs underlying cultural myths have been constructed from the experiences of teachers first as learners, then as professionals (Hashweh, 1987; Hewson & Hewson, 1987). Constraints of school contexts such as instruction time, planning time, class size, organizational expectations, as well as parent expectations, also have been reported to negatively influence reform efforts (Czerniak & Lumpe, 1996; Crocker & Banfield, 1986; Krajcik, Blumenfeld, Marx, & Soloway, 1994). This teacher change literature answers many questions related to reasons why change and implementation of reform-based ideas are infrequent.

Quantitative reports often tended to emphasize *whether or not* an innovation was implemented successfully, not *why or why not* implementation occurred. Qualitative studies have answered *why not* questions related to teacher change, with an emphasis on identifying barriers to implementation. However, little is known about the less common cases of volitional implementation.

Teachers are the crucial bridges in the translation of curricula into individual lessons. Lesson planning and implementation are determined by the goals and purposes of each teacher (Roberts, 1982). The vision of science education presented in the National Science Education Standards [NSES] (NRC, 1996), when interpreted by each individual teacher, is adjusted to individual contexts through their perceptions of their own needs as well as their students' needs. If we are to provide better professional development opportunities for teachers, as well as the necessary infrastructure to support change, it would be helpful to have a better understanding of why and how teachers implement curriculum changes. Looking at implementation from the teacher's perspective may provide answers to the why questions. How are some teachers able to implement changes in their practice when others report inabilities to change due to various perceived constraints? What are the ways that these teachers make sense of their implementation efforts? Qualitative methods are more suited than quantitative to answer in-depth questions of perspective.

Purpose and Research Questions

Following participation in a yearlong professional development program centered on biotechnology, I was interested by examples of teacher participants that appeared to have found a path to implement innovations in their classrooms. What were the ways that

their practices made sense to them? In order to understand the ways in which some teachers have demonstrated the ability to implement innovations where others' efforts have been hampered by various reported constraints, the purpose of this study was to understand curriculum implementation from the perspective of teachers who have implemented innovations following participation in a biotechnology professional development program. An overarching research question was used to guide this study: what are the perspectives of teachers who have implemented changes in curriculum and/or pedagogy following their participation in the professional development program (BISCITS) as revealed through their own stories? Sub questions were:

a. In what ways do implementors describe themselves as teachers of science? In particular, how do they describe their goals and purposes for teaching science?
b. How do implementors describe the ways in which they have incorporated innovations from the summer professional development experience (content and pedagogy) into their curriculum?
c. What are implementors' rationales for incorporating innovations into their curriculum?
d. In what ways are implementors' approaches to and rationales for incorporating innovations connected to their goals and purposes for teaching science?

Context of the Study

The prevalence of biotechnology-related topics in the current news and products of biotechnology such as disease therapies and genetically engineered foods have or will impact every citizen. This is a prime example of why updated science knowledge is as

important for everyone in today's society, and scientific literacy for all students is a worthy and necessary national goal (NRC, 1996; AAAS, 1993). Molecular biology and biotechnology are not subjects commonly found in the coursework requirements for newly trained secondary biology teachers, let alone the current teacher workforce. In response to this problem, The Biotechnology Initiative for the Systemic Change in the Teaching of Science (BISCITS) project was a systemic initiative funded by the Teacher Enhancement Division of the National Science Foundation (NSF) from 1995 until 2000 (ESI-9454397).

The major goals of the program were to develop teacher participants' understanding of contemporary concepts and laboratory skills in molecular biology and biotechnology, develop pedagogy applicable to all students in life sciences and chemistry grades 7-12, and provide support mechanisms to increase the likelihood of implementation in the participant's classroom or laboratory. The program components also endeavored to encourage and support leadership such that the participants would be able to share newly adopted curricular materials with their peers.

Held on the campus of Clarion University of Pennsylvania, the project was designed and led by a science teacher educator and a molecular biologist in collaboration with two experienced secondary biology teachers. The program design revolved around a four-week summer residential program on the university campus with three follow-up workshops during the following school year and continuing support of implementation efforts. This support was provided via on-site visits by program staff, loans of equipment and supplies, email and phone contacts, and a web site of lesson plans and resource links.

During each summer program, 18-24 biology, chemistry, and general science teachers from across Pennsylvania participated in the program. These grades 6-12 teachers had the option of earning four graduate credits as they participated in laboratories, lectures, activities and field trips designed to expose them to the principles, tools and techniques of biotechnology as well as explore reform-oriented pedagogies appropriate for secondary science.

Research Methods

The study was designed as a multi-participant case study of innovative curriculum implementation (Merriam, 1988). The identification of teachers with the high levels of implementation during and following their participation in the BISCITS program was based on several criteria: equipment lending records, logs of phone and emails containing questions pertaining to implementation, formal and informal classroom observations by members of the BISCITS staff, and anecdotal records of personal communications. Three secondary science teachers were purposefully selected (Marshall & Rossman, 1999) as participants on the basis of their completion of the BISCITS program and documented implementation of BISCITS lessons. The three participants' (pseudonyms) were David, a middle school science teacher for 15 years; Anne, a teacher of grades 10-12 life and environmental sciences and physical science for 5 years; and Erin, in her third year of teaching grades 9-12 biology, environmental science, physical science and computer technology. The examination of three participants with varying years' experience as well as different grade level and subject teaching assignments allowed the examination of similarities and differences in their various perspectives on the phenomenon of implementation (Moustakas, 1994), and adds to the depth of data for the case study.

The primary source of data for this study was a series of four in-depth, ninety-minute interviews (Seidman, 1998). Seidman's (1998) structure of phenomenologically based interviews was used to collect the teaching stories, views, and perspectives of these implementation efforts. The depth of these interviews allowed me to collect personal stories – experiences told from the viewpoint of the teachers, and then to explore in depth what these stories meant to the participant, and how these stories of implementation made sense to them and influenced these teachers' practice. Other sources of data included field notes taken by the researcher and artifacts collected while conducting site visits.

Data were analyzed inductively with pattern coding strategies allowing for the emergence of within and across participant themes associated with volitional implementation. These themes were tested against the data to determine their legitimacy and were further refined. This grounded theory (Strauss & Corbin, 1998) approach resulted in the final assertions.

Findings

Following the traditions of case study and grounded theory, this section presents assertions that are the result of my analysis and comparison of the three individual participants. There were several common themes that appeared during data analysis of the three teachers' stories of implementation. Assertions have been generated through the constant comparative technique where the researcher develops theories that are grounded in the data, explains and summarizes the themes. Table 8 summarizes the results of each participant description as related to the research questions.

Table 8 Participant Summaries: Relationship of Participants' Stories to Research Questions

	Major Goals and purposes	Story of implementation	Rationale for implementation	Ways implementation helps meet goals
David Science 8	Teach concepts and processes of science, not just facts Students learn social skills of cooperation to facilitate problem-solving; workplace skills	Integrated BISCITS lessons into mini-unit Supplemented with bioethics discussions	Facilitate students' learning of abstract concepts Bioethics discussions foster individual and group decision-making	Provided new background knowledge and new ways of structuring lessons to meet goal of conceptual understanding
Erin Academic Biology I & II	Academic preparation	New unit on genetic engineering and electrophoresis - supplement text with molecular biology content and lab skills	Facilitate success in college courses	Supplement teacher background knowledge – update curriculum
General Science 9	Help students recognize the importance of science in their personal lives	New project-based unit in forensic science	High student interest topic Vehicle for inquiry	Socially relevant topic - an application of biotechnology that would interest students
Anne Applied Biology10	Learn science as applied concepts, and help students recognize the importance of science in their personal lives	New unit on corn reproduction, genetics and genetic engineering New unit on DNA fingerprinting	Many students work on farms detasseling genetically engineered corn – relevant application of genetics High student interest topic	Application of science to the students' work Application of biotechnology that is socially relevant and in current events

Assertion #1

Implementors view curriculum as dynamic. This view facilitates curriculum innovations.

In viewing curriculum as dynamic, these three implementors perceive or have designed their curriculum as a flexible guide. A dynamic curriculum view sets the stage as a background that facilitates the participants' engagement in a continuous process of curriculum adaptation. In a society that is engaged in and affected by rapid social and technological changes, a dynamic science curriculum enables the efforts of teachers to respond to the continually changing demands and needs of their students. All three of these implementors view their curriculum as a dynamic, fluid conceptual guide that can be adapted to meet the needs and interests of their students and should be continually updated to reflect contemporary topics and applications that are relevant to their students and modern society. Implementing within a dynamic curriculum view with student learning as a primary focus means that they plan around broad concepts, do not rely on their textbook for daily planning or topic sequencing, use relevant, often local topics to illustrate the science concept, and favor a project approach as a planning and teaching strategy.

All three participants' stories depict their view and utilization of a curriculum as a flexible guide, a set of overarching concepts and skills versus a fixed entity that is imposed on the students. Where there is a fixed, limiting curriculum provided by the district, they have found it necessary to break away and construct their own set of guidelines for the course. David commented:

> O boy, that is a problem, that is a major problem in our district, because our curriculum consists of the glossary out of our books, essentially. It has been rewritten to be a little bit better, but unfortunately we really need to sit down and get it together. That is a major problem. (David, 1.91)

All three participants' stories conveyed the value they place on learning science conceptually, as a process, a vehicle for problem solving, and a way of making sense of the world. They do not talk of concerns relating to content coverage, as has been found in several previous studies (Tobin et al., 1994). This is a decided contrast to the fact-laden transmission model of science that pervades so many school cultures (Munby et al., 2000). Rather than be concerned with covering a required amount of content, these implementors are guided by goals that betray their concerns for student learning issues. The participants' specific goals for teaching science will be discussed in the next section.

The lack of marriage to a textbook also is a product of the emphasis that these implementors place on goals that are not driven by memorization of vocabulary definitions. Science teachers in several previous studies (e.g. Tobin, Tippins, & Hook, 1993; Briscoe, 1993; Cronin-Jones, 1991) were found to view curriculum as a fixed and inflexible set of content objectives and vocabulary to be mastered by the students by the end of the term. This type of curriculum is typically represented by a textbook that contains much more than can be addressed in the time allotted, so the teacher is tempted to use the text as a planning guide for the term, at a pace of a chapter every two weeks, driven to move on no matter how well or how poorly the students seem to grasp the material. David described a fellow faculty member that falls in that category:

> But the one guy likes to move through the book as quickly as he can. And he feels bad if he doesn't make it through a certain amount of the book. Lets get this covered, this covered, this covered, and he has that way. (David, 1.146)

It was glaringly obvious that these three implementors do not share this view of curriculum, nor does it drive their planning, as typified by the following excerpts:

R: So is it safe for me to summarize and say that you don't follow the book?

> D: Well, no, I don't. I use the book, to me the book is a learning tool, and there is information there to be used, but if you want me to go cover to cover, forget it. (David, 1.168)

> We had a disagreement over the choice of a textbook for applied biology. Most of those [tenth graders] are about an eighth grade reading level to begin with. There is no way they can read that book. I used it as a reference only. The accompanying materials were nice, the labs were well done. That kind of made it OK with me. You can supplement it easily. You don't have to go straight by the book. So, if I get into that book maybe four times this semester, I'll be doing good. (Anne, 3.635)

> I have a lot of freedom to teach what I want. When I got here, it was explained to me in my interview that we would be rewriting our curriculum, and whatever you wanted to teach, you could teach. There were no guidelines, so I could teach what concentrations I felt were important for each subject. Which is nice, I have a lot of freedom to experiment, to find out what works and what doesn't. (Erin, 1.3)

This view of curriculum as flexible, broad and conceptual is in alignment with the recommendations of the *National Science Education Standards* (NRC, 1996): "…coverage of great amounts of trivial, unconnected information must be eliminated from the curriculum. Integrated and thematic approaches to curriculum can be powerful" (p.213). There was a common thread throughout the conversations of using state or national standards documents as a guide when reforming their curricula, not always with departmental or administrative support.

> So, basically, what we do, the three of us who go with authentic assessment, we have taken the PA standards, and in our plan book, we write down what standard we are looking at, what we are doing, so that everything we do is pretty much tied to the standards. Even though our [district approved] curriculum doesn't call for it yet. We figure we are ahead of it. (Anne, 1.125)

> Right now we are rewriting our curriculum and aligning them with the [state] standards. We are all working on it. Each department is responsible for doing that – it is very much in the planning stages right now. (Erin, 1.23)

All three participants told of lessons that were chosen for the perceived relevance of the topic to the students' interests, personal lives, or community importance. Setting the study of science in a relevant context not only provides students with a more authentic picture of science and the role of science in our modern lives, but also provides a means of getting students'

attention and keeping their interest active. There was a common thread of concern for addressing student interest levels, as they all talked of worries related to increasing levels of apathy toward school. The constant search for interesting, relevant applications was in part to address this problem of diminishing student interest in science, and in school in general.

> Real world situations mean more to them. Too much theoretical, you will loose them, they will sit there bored, and they will sit there like lumps. (David, 2.421)

> If they aren't paying attention, I can't teach them anything. You have to get their attention and spark their interest. That means that they need to be able to see that the things we study affect them directly. If they can't see the need to learn it, why it is important to them, I might as well have dolls in those seats! You know, the old 'Why do I need to know this?' (Anne, 4.727)

> We [other biology teacher] sit down and discuss what is relevant to the kids, what can they use, what can they gain from studying a certain aspect of science. We try to keep what is real and useful for them. (Erin, 1.46)

These implementors would agree with and have incorporated Paul Hurd's 1991 advice for the science education community:

> The public has been active in blaming teachers for the decline in student interest and achievement in the sciences over the past decade, but has failed to recognize that problems lie in a curriculum that students find lacking in meaning and relevance, and that has little value in life. (p.731)

Viewing curriculum as dynamic facilitates the implementation of innovations. Along with this dynamic view, all three participants either had the freedom to adapt their curriculum as they saw fit (Erin), or they took the initiative and strayed from a district document (Anne and David). The goals that they have set for their students' learning are so important to them, that they are open to try new lessons, new methods, and new technologies in their search for ways to meet their goals and facilitate their students' learning of science. They are an example of life-long learners that continue to work and grow in order to meet the challenges of sharing their love of science with their students.

Assertion #2:

Implementors hold tacit, implicit, personal goals and purposes for teaching science and their pedagogical practices are congruent with their goals despite common constraints.

The stories of all three implementors were found to relate tacit, implicit, very personal goals and purposes for teaching science. The goals were personally developed rather than adopted from a curriculum guide. The focus of their goals was consistently centered on student learning, and their planning was driven by their perceptions of the needs of their students. They often had difficulty expressing their ideas, but were able to elaborate during continued questioning and discussion, and the goals became apparent during data analysis. The preferred pedagogies that were prominent in their stories all had direct consistencies and relationships with their goals. There were no instances of misalignments between their goals, purposes, beliefs, and reported practices.

Conceptual science was a recurrent theme throughout the conversations. David talked about "main concepts", Anne spoke of "applied concepts" and Erin used the term "interrelated concepts" and "big ideas". As discussed under Assertion #1, these implementors are not bound to their textbooks, do not emphasize memorization of vocabulary, and all talk in terms of science as conceptual and an inquiry-oriented process.

David's first career in industry helped shape his belief that an important purpose of education is to prepare students with the knowledge and skills they will need to be successful in the workplace. In addition to goals related to science concepts, his goals include social skills of cooperation, coping, and problem solving.

> I asked them in industry, when you get a new employee, what are some of the things you expect? They tell me, the ability to get along with other people. They say that new employees have no coping skills, and they say that is very important. (David, 3.631)

Anne believes that an important purpose of science education is to prepare her students with the ability to understand science concepts so that they can apply them to solve problems that will arise in their personal lives, as exemplified by this statement:

> I'd like them to be able to think for themselves and to make good decisions. My kids probably aren't going to college, but they will have families to take care of, be members of their communities, and I'd like them to be able to use some basic science knowledge to better their lives. I try to show them why it is important to learn science, and how it might help them learn to solve their own problems. (Anne, 4.716)

Erin believes that the content of her courses should be appropriate for the needs of her students, but she believes that her academic students have different needs than her general, or non-academic students.

> I do tailor my goals to fit the classes. For instance, my Biology II class is a small group, but almost all of them are planning to attend a four-year college. Two are entering a pharmacy program and one wants to major in pre-med. Another is considering physical therapy. I try to keep them interested in new developments and cover the subjects that they might encounter in a college level science course. (Erin, 4.740)

Erin believes that her non-academic students will need to understand basic science concepts and principles, acquire basic technology skills, as well as understand that science can be useful in personal and social decision-making and problem solving:

> All of these kids are going to need to understand some basic science to get along in this world. This area is a prime example that the days are gone when you can expect to go to work in the same factory or coal mine or trucking company where your parents and grandparents worked and earned a good wage. You need more education or training to get the good paying jobs now. They need basic technology skills, too, no matter what

> occupation they choose. Science and technology are affecting our lives at home as well as at work, too. They are going to be faced with decisions that our parents didn't face because of new science – like the genetic testing and the effects of genetic engineering. Somehow, I have to help them see that this is important to them, to their future. (Erin, 4.701)

All three of these implementors had developed their goals for teaching and learning independently, guided by the desire to meet the learning needs of their students, rather than driven by the demands of transmitting content knowledge to students. Their planning appears to be driven by the question, "What do my students need to know and be able to do to be able to function as responsible citizens in the 21st century?" Throughout the stories, there was an overarching concern expressed for presenting content as relevant to students' lives both present and future, using methods that address their various students' learning: hands-on rather than textbook based, minds-on rather than activitymania (Moscovici & Nelson, 1998), concrete rather than abstract.

Although the interviews did not specifically focus on clarifying the various components of the participants' beliefs regarding the nature of science (Lederman, 1992), the data did indicate that these teachers' beliefs include seeing science as broad, overarching concepts and principles that can be studied and validated by the students themselves. They all indicated that they view science as a process that has resulted in a body of knowledge. David also pointed out that through history science knowledge has changed as humans have continued to use specific processes and logic to arrive at ever more accurate representations of our natural world.

> It helps them see that what we know about science has changed through history, and I hope they come to see that what we think we understand now might change someday as more is discovered. (David, 2.470)

The participants' goals for teaching science also are based on their personal knowledge and beliefs concerning the purposes of science education in secondary school and the nature of their students' learning. The goals of all three participants are student-centered, concerned with

their students' learning and directly related to and influenced by their perceptions of their students' varying needs (general vs. academic vs. middle school) in the context of the courses they teach. They all distinguished between mere hands-on activities and meaningful learning, which involves hands-on activities plus thought. For example, David believes that his middle school students need material presented in a concrete fashion, with hands-on experiences the aid them in understanding concepts.

> It helps to use models and projects with these pre-startup teenagers. They need hands-on, as much kinesthetic as possible. You have to understand that there are a lot of differences. Every lab, they have to so something that involves them, that they can see the connections, think about the concept. It has to be concrete, you know. (David, 2.341)

The participants' goals and underlying beliefs stem from their experiences both before teaching and in the classroom but their preferred pedagogy was found to differ from the commonly found practice of teaching the way that they were taught (Stofflet, 1994). The didactic methods used by some of their colleagues, which may have been most familiar from their own high school and college science courses - that of traditional lecture, lab, and recitation, have not enabled them to meet their goals and have been found lacking by these implementors. Recall these statements:

> …the one guy likes to move through the book as quickly as he can. And he feels bad if he doesn't make it through a certain amount of the book. Unfortunately, he just wants to cover the chapters, finish the book. I can't do that. (David, 1.147)

> We are young, about the same age, and I think we are kind of divisive. We are divided on – how do I say this politely? We are divided on techniques. Three of us are going more for authentic assessment. The other three are sit down, take notes; I'll give you a test on it at the end of the week. (Anne, 1.5)

> But he does tend to lecture a lot, and you can't do that to a typical kid today, especially the ones who are not motivated academically. We have a lot of the vo-tech students, and they just don't take notes. Just don't. So, he didn't adapt in that way. (Erin, 3.636)

Again, the exception is in Erin's case, where her preferred pedagogy varies within her courses along with her goals. She believes that for her academic students to acquire the study

skills and habits necessary for success in college, she should construct an atmosphere in her classes similar to what her students will encounter in college, as well as attend to the higher academic science content necessary for success in college science. The fact that college science is typically taught in a lecture format influences Erin to emulate that strategy, rather than the project approach that she favors for all her other courses and students.

> What is really interesting is that the Bio II class where I really do follow the textbook, and the other ones, the General Science is more project-based, and my Environmental Science is many projects – they go from one topic to the next. (Erin, 1.20)

> I have found that, at the college level, they don't do those things as much, it is still lecture, they still have to be able to take notes, and make a formal lab report. I want them to be able to do that. Biology is more structured. I feel like that is the way it is, when they get to college, they are going to have a more structured environment. I keep it a little bit more formal. (Erin, 1.85)

Aligning with their goals for science as conceptual, non-factual, and a process of finding answers to questions, the participants' have adopted a project approach and authentic assessments rather than text-book based lectures, worksheets, and objective tests that lend themselves to managing the constraints of time and class size, as well as the issue of control in the classroom.

In all the stories of teaching, the participants often used the term "project" to describe a preferred teaching strategy consistent with their view of dynamic curriculum. Although the participants' use of "projects" has a number of features in common with project-based instruction (Krajcik, et al., 1994), problem-based learning (Glasgow, 1997), and authentic assessments (e.g. Arlington County Public Schools, 1997), their use of the term was not informed by the research literature. The continued use of the term "project" within this report is an attempt by this researcher to represent the participants' ideas as authentically as possible. I have used the term "project approach" to indicate the generic use of the term by the participants.

These implementors value various types of projects as curriculum vehicles for presenting relevant content conceptually integrated with the skills of inquiry in an environment that fosters student participation and success in science class. The focus, problem, question, or product that

forms the basis of the project can change from class to class and from year to year and still meet the science concepts and skill requirements of their curriculum.

All three of these implementors do not value a quiet classroom where the teacher does all the talking and has all the answers.

This quote from David expresses their collective view:

> Really cool, if you give them a little room to be creative, they will do it. Letting go, you know there is a fine line of control in a classroom. You have to set goals for them, and you have to have guidelines, but you have to let go and let them take over a little bit. (David, 3.498)

It is important to note that the preferred pedagogies of these implementors, predominantly student-centered and project-based, are markedly in alignment with their goals and supporting beliefs. There was a noticeable lack of references to frustrations caused by the constraints of their classes, students, schedules, or budgets. This does not imply that the conditions perceived as constraints do not exist in the workplaces of the participants, rather that the participants do not perceive their sometimes difficult conditions as constraints!

The use of a project approach enables these implementors to work toward their goals of science as conceptual, process-based, relevant, and interesting to their students. This is a contrast to the conflict in beliefs and practices found in some previous studies where implementation of innovations was infrequent and change was slow (Pajares, 1992). Fang (1996) reviewed the literature on the relationship between teachers' beliefs and practices and concluded that there are two themes contained in this literature: a consistency or an inconsistency between beliefs and practices. One line of research finds a consistency between the beliefs and practices of teachers, and another line of research finds that practices are not always consistent with beliefs, due to constraints felt by the teacher within the school context. Several researchers have found that the various features inherent in the current structure of schools such as the school

culture (Munby et al., 2000), short class periods (Harry, 1996), large class sizes (Tobin et al., 1990), and expectations of administrators and parents can act as constraints and result in teaching practices that may not be congruent with a teacher's beliefs (Richardson, 1995; Tobin & McRobbie, 1996). In this study, the descriptions of the participants' schools, students, and class assignments illustrate that they are faced with these same common constraints. Yet, the actions as conveyed in the stories of these implementors indicate that they have found ways to meet their goals despite the difficulties imposed by constraints.

All three participants chose to implement new lessons and methods that aligned with their goals and aided in their efforts to meet their goals. Topics and methods of teaching biotechnology that were reported addressed the teachers' concerns for student interest and conceptual understanding. There was no incidence reported of changes in preferred pedagogy after the professional development experience. Pedagogy was not the primary focus of the workshop, but secondary to biotechnology content, and these teachers did not perceive the methods used by the staff to be radically different from their current practice. This finding agrees with that of (Borko, 1997), who stated, "when teachers' beliefs are compatible with the ideas that underlie a staff development program, these beliefs support the change efforts" (p.236).

The participants all reported implementing lessons used as models during the BISCITS workshop (e.g. Marsh'uns, DNA Spooling, Rainbow Electrophoresis, Appendix D). The participants had been engaged as learners using these lessons, and used these model lessons to teach biotechnology-related topics to secondary students during the last week of the summer workshop. They were very familiar with not only the concepts of the lessons, but the pedagogy used in the design of the lesson. The lesson-planning strategies and research-based theories used to design the lessons had been explicitly discussed as a separate activity. All three participants

reported adopting lessons written with reform-based pedagogical strategies taught in the workshop, and implementing these lessons with few if any changes.

> The BISCITS lessons are well written, and we had tested them, so I knew I could use them just as they were. (David, 2.426)

> For the most part, I do it [BISCITS lesson] the same way. I don't improvise a lot. Maybe I'm not creative, but I found that there wasn't really anything to change! I am comfortable with it. (Erin, 2.366)

However, a limitation of this study is that the reports of use of these lessons without adaptation of the underlying lesson planning model used in their construction could not be confirmed without direct teaching observations. However, it appears that the scaffolding provided by the participants' comfort level with the model lessons was an important factor in their implementation, as well as leading to the participants' construction of new lessons expressly designed for their purposes and contexts as conveyed in the stories of implementation. Of the three participants, only Anne was familiar with the term scientific literacy, yet all the goals reviewed in the participant descriptions (Chapter Four), with the exception of Erin's concern for preparing her academic students for success in college, reflect the vision of scientific literacy as offered by the *National Science Education Standards* (NRC, 1996). It was noted that all three teachers place importance on their students acquiring the ability to apply scientific concepts to personal and societal problems, the skills and attitudes of life-long learners, workplace skills, and decision-making skills, as exemplified by these statements:

> You know, even if they don't find science as interesting as we do, I want these kids to see that it is useful to them, and scientific thinking can help them solve problems. (Anne, 3.659)

> A big goal is to learn how to learn. That's it. No matter what you throw at a student, if you learn how to learn, where to find information, and how to make sense of it, then I feel like I've done my job. (David, 1.147)

There was also a science, technology and society theme in their choice of projects, as well as the theme of the history and nature of science in David's stories.

> It helps them see that what we know about science has changed through history, and I hope they come to see that what we think we understand now might change someday as more is discovered. (David, 2.470)

Even though some authors have argued that higher levels of scientific literacy for all as outlined in documents such as the NSES and Benchmarks are lofty and unattainable (Shamos, 1995), these teachers see value in working toward the higher levels within the goal of scientific literacy. The memorized vocabulary of the lower level functional scientifically literate graduate is not satisfactory for these three implementors. By designing STS oriented projects (David, Anne, and Erin), including the history (David) and nature of science (David and Anne) the level of Multidimensional Literacy was not considered out of reach. David, Anne, and Erin's personal goals encompass a foundation of conceptual knowledge and process skills, problem-solving applications, as well as the skills and attitudes for continued life-long learning.

These teachers valued the BISCITS program for the many reasons, but a predominant value was put on the perceived contemporary relevance of the content. Biotechnology topics were invariably chosen for implementation because they are highly relevant applications of genetics concepts that are interesting to students, timely, newsworthy, and are likely to affect students' personal lives. The popularity of lessons featuring DNA applications in forensics as well as the bioethics discussion models indicate the important connection these biotechnology lessons provide to timely issues likely to affect all citizens of the 21st century.

Assertion #3:

Implementors' deep sense of professionalism drives them to explore innovations.

Teaching in the United States is not now regarded as a profession. There is little hope it will ever become one until we develop a commitment to research and find ways for using its results to advance our professional responsibilities. Once we effect a system that will bridge research and practice, our professional status will be close at hand. (Paul DeHart Hurd, 1991, p.729)

The current work environment for most teachers in the United States is anti-professional (Clifford & Guthrie, 1988). What does it mean to be a professional? Members of other professions, such as medical personnel, lawyers, engineers and architects, are trusted and respected, seen as experts in their fields, and highly rewarded for their knowledge and work. That teachers are not awarded the same trust, respect, and rewards belies a lack of trust in our educational system and a pervasive anti-intellectual streak in the American culture (Clifford & Guthrie, 1988). That some teachers such as these have not given in to the unfortunate anti-teacher, anti-education attitude is a credit to their own self-confidence and dedication. Teachers, more often than the educational system, are blamed for everything from high dropout rates to low achievement test scores. Teachers are often treated as little more than skilled workers, implementing directives that trickle down from upstairs in the form of policies, standards, and 'teacher-proof' curriculum guides (Loucks-Horsley et al., 1998). For too long, teachers have been expected to implement curricula that have been designed by experts outside the classroom. For too long, conditions such as these have rankled teachers who have great ideas born of their own creative professional and practical knowledge.

> But we really begged, every time we have an inservice, we say – why don't we sit down and address this – and they just – it seems like they are afraid to trust us as professionals, and I don't like that, at all. Why do you treat me just like I am a student? And yet, any other professional, you're given the feeling that you are trusted with what you work with. (David, 1.111)

How can we complain about the lack of professional treatment by the public when teachers' own administrators do not trust them as professionals? Just under the surface of their

determination was an unabashed love for their students and pride in their chosen profession. David, Anne, and Erin are proud to be educators and work long hours to reach a level of excellence that wins awards in other occupations. In fact, David did win Teacher of the Year for his district a few years ago and the plaque hangs prominently in the teachers' lounge. However, that award year has come and gone, and he still feels like his work is unappreciated by his administration. Even though they may not always be treated as professionals, they still know that they are professionals and more importantly, they act as professionals.

What are the characteristics of these particular professionals? They are well educated, experienced, and independent. They still enjoy going to work each day. They have deep, personally important concerns for their students. They value their autonomy and enjoy the freedom to design their own curricula. They have pride and ownership of their course plans, and continually refine their plans as they work toward their personal goals. Their conversations did not contain the language of frustration at being a target of reform – they are reformers themselves. Their continuing search for knowledge led them to participate in the BISCITS program. They were there because they wanted to be there, not because they were obligated to attend.

> I had tried to come to that for years! I just thought it would be interesting! It was the flyer, the whole concept of biotech and genetic engineering. I like genetics anyway. But it was that whole concept that fascinated me. (Anne, 3.608)

> R: Can you tell me what led you to take BISCITS that summer?
> D: Well, I'm incredibly weak in genetics, number one, and I try to take a course every summer. (David, 3.711)

Most importantly, all three of these implementors are risk-takers. They are comfortable with the risks inherent in straying from the school culture and doing things differently. In fact, they do not see it as risky, but necessary.

> D: The first year I pretty much played the game the way as the woman beside me. She was all worksheets and reading. The kids stayed in their seats, all the flowers in the same row. And they never did anything. And I knew I had to break away, I wanted to do something off the wall.
> R: Why?
> D: Because I thought there was a better way to do it. I didn't think they were really learning anything. (David, 3.522)

> One of the things about M's room or my room, because we do these different types of assessment, our rooms are noisy. And the kids are not in their seats in a nice straight row, perfectly quiet, and some people frown on that. That bothers them, that we don't have control over our classroom! (Anne, 3.623)

> No, I always threaten at the beginning of the year that if you don't behave, we won't do the labs. But we do them. If you have a class of 30, they are loud and noisy; but if they are on task, we do it anyway. If they are learning, it is important and I don't take it away from them. (Erin, 4.547)

They do not shy from the risks inherent in the introduction of a new lesson or unit. The chance to practice the BISCITS lessons during the summer workshop had raised their confidence to teach these particular lessons, but trying the new in their classroom is not unfamiliar to them. That is how they continue to learn.

A Portrait of Implementors

During the construction and reconstruction of the results summary, an overall image of an implementor appeared. I realized that all of the assertions emerging from my analysis efforts were interdependent. As in a portrait, the features of this case of implementation were parts of a whole, characteristics that when assembled form a unique profile. Each assertion paints only a piece of the entire portrait. To understand these implementors, you must view each piece as belonging to the whole, not complete without the others. As in the bone structure of a face, the first assertion of a dynamic curriculum view is overarching, the background and support for the other three. Without this particular background structure, the other features would not have the

same overall profile. Features in this portrait of implementors are formed by a vision of scientific literacy, aligned goals and reported practices, and a beaming smile of professionalism.

Conclusions and Recommendations

The participants of this study enjoy the freedom to either design their own curricula or substantially alter their district curriculum plan to align with their goals. Agreeing with Ben-Chaim, Joffe, & Zoller (1994) and Richardson (1992), it makes sense that teachers must be involved in the decision-making processes involved with curriculum reform. Howe and Stubbs (1996) designed a socio-constructivist model of professional development where teachers were provided the tools and opportunity to construct their own knowledge. Howe and Stubbs conclude, "when teachers have the freedom to make choices and to take responsibility for their own futures as professionals, they gain a sense of their own power, which is to say they become empowered" (p.179). Anne, David, and Erin are examples of such empowered professionals. They have voluntarily sought and taken advantage of continuing professional development opportunities and regardless of years of experience, have all become teacher-leaders in their districts.

The results of this study indicate that policy-makers should encourage and support the work of teacher-leaders by valuing their expertise and inviting them to take the lead in redesigning curricula. One policy recommendation arising from this study is that these isolated reform-minded teachers should not only be identified, supported, and commended, but placed in positions of leadership that take advantage of their teacher-leader capabilities.

Teacher-leaders are too often under-appreciated if not stifled, and more critically, they are an under-utilized resource for educational change. Real changes in teaching practice are found in isolated instances of individual teachers often working alone and unsupported. The

science education community would be wise to value and utilize their leadership. National and especially state level policy-makers might do well to avoid policies that act *on* teachers, and work to adopt policies that work *with* teachers. Reforms in science education are often spoken of in terms of sweeping changes needed for improvements, with little attention being paid to pockets of local reform activities that have sprung up in response to national policy documents such as the NSES and the *Benchmarks*. More research is needed to identify local reform agents and activities already in place and study the effects of such efforts.

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